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IALA Guidelines on the "Selection of rhythmic characters and synchronization of lights for aids to navigation (G 1116)" Edition 1.0, December 2016

Transmitted by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA)

Mandate

1. This document is submitted in line with cluster 5: Inland Waterway Transport, paragraph 5.1 of the programme of work 2018-2019 (ECE/TRANS/SC.3/2017/24) adopted by the Inland Transport Committee at its eightieth session (20-23 February 2018).

2. At its fifty-second session, the Working Party on the Standardization of Technical and Safety Requirements in Inland Navigation decided to consider IALA Guidelines "Selection of rhythmic characters and synchronization of lights for aids to navigation (G1116, December 2016)" as a basis for possible amendments to SIGNI (ECE/TRANS/SC.3/WP.3/104, para. 32). The IALA Guidelines are reproduced in the annex.

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Annex

1. Introduction

This document is intended for the provision of guidance to the technical aspects of selecting the rhythmic characters as defined in Recommendation E-110 [1]. It includes temporal considerations, selection of colours, the use of the fixed and flashing character, user considerations, synchronisation and sequencing.

While the selection of a rhythmic character for floating AtoN is a straightforward process strictly guided by E-110, there are many options for selection of a rhythmic character for a fixed AtoN. When selecting a rhythmic character for a fixed AtoN, one should first consider the navigational aspects (significant difference from nearby marks; conspicuity, terrain and the background lighting; etc.). Then the technical aspects, such as, power requirements must be considered which may require a second iteration of the character selection.

2. Background

Historically, there were technical limitations in the achieving the characters available in E-110. However, in the foreseeable future the majority of AtoN lights on fixed and floating AtoN will be converted to Light-Emitting Diode (LED) or other emerging light sources. There is much more scope in the selection of rhythmic characters to exploit with these new technologies.

3. Scope and purpose

This document applies to marine aids to navigation signal lights on fixed and floating applications. It is intended for provision of integrated guidance on the following topics:

- General temporal considerations
- Selection of colours
- Flash duration
- Character length
- Use of simultaneous fixed and flashing signals
- Synchronisation and sequencing
- Sharing of good practice by inclusion of examples in appendices.

4. General temporal considerations

4.1. Considerations for period selection

The persistence of vision of a light, after extinction of the light, can reach 0.15 second. If the duration of an interval of darkness in a rhythmic character is made too short, the flashes may merge, obstructing identification of an AtoN. Therefore, duration of an eclipse should not be reduced to under 0.15 second.

The periods of the characters of rhythmic lights should be selected in accordance with location specific navigational requirements and results of corresponding risk assessments.

Restricted areas, heavier traffic and higher vessel speeds need shorter periods and longer or more flashes in characters allowing more rapid and frequent identification. In less demanding areas with little traffic and slower speeds, it is more acceptable to use longer characters.

Historically, periods of up to 30 seconds have been used for major landfall lights. Where possible in new installations, a shorter period should be considered in order to reduce the time necessary to identify the AtoN.

In order to maintain spatial awareness in demanding areas, consideration should be given to limiting the eclipse length. Trials have shown that limiting the eclipse length to 8 seconds has proved to be effective [23]. When longer eclipse is required to avoid confusion with other lights, introduction of a fixed and flashing character can be used to retain spatial awareness at close ranges. Fixed flashing can also be considered for shorter eclipses when high-speed craft or close manoeuvring to the aid to navigation is expected.

4.2. Considerations for flash length selection

To ensure that their quick lights can be discriminated, an authority should preferably choose the rates for all its quick lights to be 60, very quick lights 120, and ultra-quick lights 240 flashes per minute. The repetition rate for ultra-quick lights should not exceed 300 flashes per minute because at faster rates the sequence of flashes might resemble appearances of steady light in some circumstances.

Discrimination of different rates of flashing is not immediately easy unless there is a ratio of at least three to one between the rates. If this ratio cannot be attained, particular care will be required if flashing, quick, very quick and ultra-quick lights of the same colour in the same area are to be correctly and readily identified. Other distinctions should be made, if possible, between the characters, such as making periods clearly dissimilar or the numbers in groups different.

The term "long flash", which is used in the descriptions of the long-flashing light and of the light characters reserved for south cardinal marks, means an appearance of light of not less than 2 seconds duration. The term "short flash" is not commonly used and does not appear in the Classification [1]. If an authority requires discrimination between two flashing lights that only differ in having flashes of different durations, then the longer flash should be described as "long flash" and be of not less than 2 seconds duration, and the shorter flash may be described as "short flash", but its length is no more than one third of the duration of the longer flash.

Several countries have defined specific rhythmic character subsets for use mainly on their floating marks. Examples of national flash characters are provided in [11], [12] and [13]. An example of implementing different rhythmic characters for a channel is to increase the number of flashes in accordance with the distance along the channel. Another example would be to use a different flash character of lateral buoy lights at a change in channel direction.

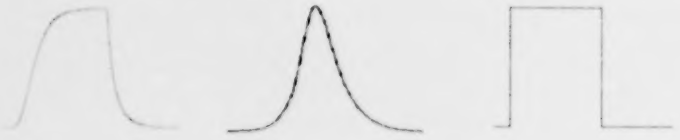
4.3. Considerations for flash shape selection

Traditionally, flash shape has been confined by technology, resulting in flash profile that cannot be precisely controlled. Gaussian flash profiles produced by rotating optics and incandescent sources had a side effect of perception of the flash length changing in accordance with the viewing distance that provided certain ranging capability at the far end. Standard rectangular flash shapes produced by LED light sources retain same temporal perception regardless of the viewing distance.

However, with the use of modern control technics and LED light sources, bespoke flash profiles can be achieved which may assist in conspicuity and ranging. Impact of flash profile manipulation on effective luminous intensity of the flash pulse is explained in [3].

Figure I

Typical flash shapes (pulse profiles) produced by flashing incandescent light sources (left), any light sources in rotating optics (middle), and rectangular LED pulse (right)



5. Selection of colour

It is safer to assume that a confusion between white and yellow as colours for lights is liable to occur, and therefore the rhythmic character of a yellow light should always be chosen with the understanding that the colour of the light might be mistaken for white.

A green or blue light that is showing flashes of very short duration can be mistaken for a white light. Therefore, authorities should take care that the colour of a green or blue light is clearly recognizable at the maximum required range if the duration of a flash in the rhythmic character is very short. It is advisable for authorities to avoid choosing rhythmic characters with high rates of flashing for blue or green lights.

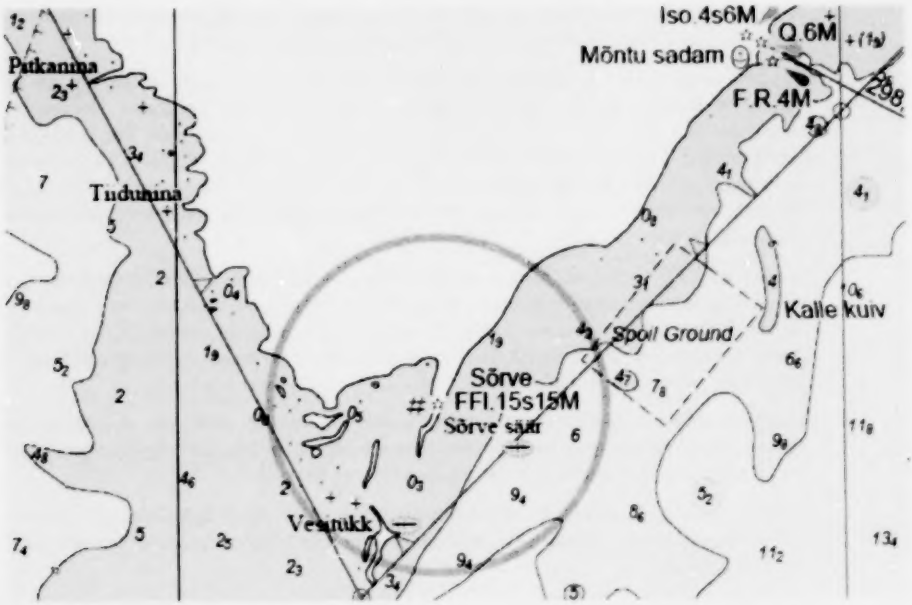
Use of colour in AtoN signalling is described in detail in the IALA Maritime Buoyage System.

6. Use of fixed and flashing signals

Replacing an eclipse of a rhythmic character of AtoN light with a low-intensity light signal enhances the ability of the mariner to maintain spatial awareness and improves identification at close range. In cases when traditional rotating optics of a lighthouse are replaced with flashing LED lights, implementation of fixed and flashing character creates the effect similar to the residual light between flashes of rotating optics. Trials have shown that a fixed light signal component of 1 per cent of peak luminous intensity can be considered sufficient for majority of fixed and flashing character applications. Careful consideration of conspicuity implications is necessary to avoid reduction of fixed/flashing component contrast by fixed luminous intensity level above 5 per cent (up to 10 per cent in high background lighting conditions).

The fixed component can be applied to a number of rhythmic characters, if the low intensity phase (longest eclipse in the group character) is longer than the high intensity phase (flash). Nevertheless, fixed phase can be also used with occulting characters. For charting purposes, placement of an "F" in front of the character abbreviation signifies application of a combination of the low intensity fixed light signal with the main character, shown in Figure II. For example, the following abbreviations are already in use: FFl, FIso, FLF.

Figure II
Chart fragment showing a 15 NM FFl light (Estonian AtoN 935, Sõrve Lighthouse)



This class of light character should be used with care because the fixed component of the light may not be visible at all times over the same distance as the rhythmic component due to environmental factors.

Some results of trials and application examples are provided in [9] and [10].

7. Synchronisation and sequencing of AtoN lights

7.1. Introduction to synchronisation and sequencing

Synchronisation and sequencing of AtoN lights are useful methods of increasing spatial awareness of mariners by improving the overall conspicuity of AtoN lights especially in built-up areas and areas with background lighting.

Both can be combined with fixed and flashing rhythmic characters.

Where possible, effect of sequencing of lights can be tried out on an AtoN lights simulator before deployment to evaluate the benefits.

Improved availability of GNSS timing signals provides a cost efficient method for synchronisation and sequencing of AtoN lights. AtoN light units with integrated GNSS receiver modules are offered at relatively low cost by a number of manufacturers.

In addition to the objective of this Guideline, there are other applications where synchronisation may apply, as reflected in corresponding IALA documentation addressing marking of manmade structures [21], wind farms [22], or on other types of objects, such as wrecks, or when the identification of the "geometry" is relevant to the mariner.

7.2. Application of synchronisation and sequencing

In seeking to meet the navigational requirement as identified by risk assessment, the option of using synchronised and/or sequential lights provides a useful augmentation/enhancement to conventional AtoN lights when viewed against background lighting.

Synchronising of two or more flashing lights is already in use in signalling systems for various transport systems, including road, rail, aviation, and maritime. Historically, synchronisation has been used in the maritime world for leading lights. The purpose of synchronising is to increase the conspicuity of the signal, and/or to indicate that the two or more lights are associated in some manner. For example, if two buoys form a "gate" in a channel, the lights on them might be synchronised to make that gate pair more conspicuous, improving spatial awareness.

Sequencing of lights occurs when a series of lights are flashed in a time sequence to show the geographical relationship between them. Such a set of lights is sometimes likened to a so-called "flare path" or "runway" effect. In certain applications the number of flashes in the rhythmic characters of associated AtoN lights is increased (decreased) in progression along the fairway while only two of such lights are visible to a mariner at a time.

It is also possible to combine the two effects, so that, for example, if there is a channel marked by pairs of buoys, the lights on each pair are synchronised, and in addition, the paired lights are set to be in a time sequence along the length of the channel.

In each case, the objective is to help the mariner distinguish which lights are pairs of buoys (or beacons) marking a channel, and in addition to indicate which pairs are closest and which are more distant.

Following extensive trials [14] and experience gained with both synchronised and sequential AtoN, it is clear that two key benefits can result from their use:

- Synchronised lights provide high impact conspicuity

  They draw the observer's eye to their presence and overcome background lighting due to their regular and combined effect.

- Sequential lights provide directional awareness and improve positioning within a system, e.g. fairway

  The observer experiences visual movement in the horizontal plane.

The results of a number of these trials are available at the IALA Wiki.

7.3. Considerations for implementation of synchronisation

The flashing sequences of AtoN can be synchronised in a number of different ways. The devices should flash in a particular order for the fairway to be the most conspicuous to the mariner. Guidance based on current best practice is provided below.

7.3.1. Testing configuration for optimum conspicuity

It is important to test or simulate the synchronisation of flashing lights on one fairway in different conditions before making decisions on the synchronisation method to be introduced. This will allow an assessment to be made as to the extent that the visibility of the fairway can be improved. Tests should also involve affected mariners in order to ensure that the optimum system of synchronisation is implemented for a particular application.

7.3.2. Logical grouping of lights

Fairway turning points can be used to divide the fairway into sections. Lateral marks of the same fairway section could be synchronised, after which the aids marking the next section could be turned on. In order for the various fairway sections to stand out they should have similar characters. If this is not possible, the flashing sequences should be in multiples of each other's light periods.

Another possible option would be to follow the example of airport runway lights, which are turned on in sequence (consecutively). This alternative could also be utilised to guide vessels to port, however, this may look peculiar when leaving port. In this alternative, the flashing sequences at the ends of the fairway should be different from those in the middle. This method is not advisable in a shipping lane where the AtoN are not placed at equal intervals. As the distances vary, it is not possible to create an "approach effect" similar to an airport.

A third option would be to synchronise the different sides of the fairway. Using this method, the direction of the fairway could be highly visible but detecting its width could be difficult.

7.3.3. Use of different characters

Different characters can be used effectively to identify the beginning of a fairway or change in the fairway. For example, the first two buoys or channel markers could have a different character from the rest of the channel, whilst remaining synchronised.

The character period of synchronised lights should be sufficiently short such that the observer can see those aids as frequently as possible.

7.3.4. Sequential flashing

For lights flashing sequentially, the sync delay needs to be determined taking into account the geometry of the channel and in particular the paired buoy spacing. As a guide - "the closer the buoys are together the shorter the delay may be".

The geographical spacing between synchronised lights within a group, on fixed or floating aids, should be such that the group as a whole is normally within the observer's field of view.

When selecting flash character of sequencing lights and/or pairs, effect of sync failure on identification of such lights should be considered.

7.3.5. Leading lights

Selection of characters and management of synchronised leading lights ([20], [15]) should be such that the front and rear lights can be identified easily, and an overlap of their flash "on" time can still occur in the event of sync failure.

Special consideration should be taken in the design of synchronised leading lights to ensure that in the event of the failure of one lead, a single light is not mistakenly paired with an apparently synchronised external source such as its reflection on water. This consideration could include an automatic disabling of the second light if after risk assessment this is required.

7.3.6. Other considerations

1. The geographical layout and mix of the aids to navigation, channel or port approach where synchronised aids are deployed should be considered as a whole before decisions are made to establish such aids.

2. The likely sea state and prevailing visibility, i.e. local conditions, should be considered when planning to use synchronised or sequential lights in a waterway.

3. At dusk when the lights first turn on, and on occasion due to synchronisation signal loss, there may be a period of time where one of more of the lights will not be in synch,

therefore, consideration should be made to the general layout of the aids to navigation to ensure the mariner can still identify the channel.

4. The preference of using grouped synchronisation over sequential synchronisation may be made to avoid confusion to the mariner when transiting in an opposite direction to the sequential flashing.

5. Promulgation of information by way of notice to mariners must be carried out informing the mariners when a synchronised system is put in place.

6. Affected stakeholders should be consulted when designing the synchronised system.

7.4. Limitations of synchronisation

7.4.1. Environmental limitations

The application of synchronised and/or sequential aids to navigation does not necessarily provide the mariner with positional information. Synchronised lights provide spatial awareness and orientation within a channel or system of aids to navigation. There are physical limitations with regard to the installation of equipment required for synchronisation systems, e.g. lights synchronised using the GNSS must ensure that the GNSS sensor has an un-obscured view of the sky in order to receive regular timing signal updates. Atmospheric conditions may affect the signal strength for radio synchronisation systems.

It should be considered that power requirements to provide a synchronised light system will in general, be a little greater. The impact of synchronised/sequential lights can be adversely affected by: buoy stability, visibility, excessive height of eye vis-à-vis vertical divergence, and general adverse weather and sea conditions (in a manner similar to conventional marking).

7.4.2. Maximum slippage time

To ensure the mariner can clearly ascertain synchronised groupings the timing error between synchronised lights should not be greater than 50 ms [12].

7.4.3. Minimum angular separation

To ensure clear separation of individual synchronised lights can still be made, it is recommended that there should be a minimum angular separation of 5 minutes of arc, subtended at the observer [12]. Lights too close together may be appearing as a single light of a unique and different colour.

8. Acronyms

AtoN Aid to Navigation

FFl Fixed and Flashing

Flso Fixed and Isophase

FLFl Fixed and Long Flashing

GNSS Global Navigation Satellite System

GPS Global Positioning System. Operated by the Government of the United States

IALA International Association of Marine Aids to Navigation and Lighthouse Authorities - AISM LED Light-Emitting Diode

ms millisecond(s)

9. References

[1] IALA Recommendation E-110 on Rhythmic Characters of Lights on Aids to Navigation

[2] IALA Recommendation E-200-0 on Marine Signal Lights - Overview

[3] IALA Recommendation E-200-1 on Marine Signal Lights Part 1 – Colours

[4] IALA Recommendation E-200-2 on Marine Signal Lights - Calculation, Definition and Notation of Luminous Range

[5] IALA Recommendation E-200-4 on Marine Signal Lights, Part 4 – Determination and Calculation of Effective Intensity

[6] IALA Recommendation E-200-4 on Marine Signal Lights - Determination and Calculation of Effective Intensity

[7] IALA Recommendation E-200-5 on Marine Signal Lights - Estimation of the Performance of Optical Apparatus

[8] IALA Guideline 1069 – Synchronization of Lights

[9] Fixed Flashing Lights Viewing Trial. Malcolm Nicholson. Presentation at IALA ENG1

[10] Trials and Implementation of the Fixed and Flashing Rhythmic Character on Estonian AtoN. Aivar Usk. IALA ENG1 input paper ENG1-9.4.4

[11] National AtoN character list (German list). Frank Hermann. IALA ENG2 input paper ENG2-9.5

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[13] National AtoN character list (French list). Yves-Marie Blanchard / Michel Cousquer. IALA ENG2 input paper ENG2-9.12

[14] GLA R&RNAV Technical Report No. RPT-09-03-MN-IT-07, Synchronised Lights Viewing Trial, August 2007

[15] IALA Guideline 1023 for the Design of Leading Lines

[16] IALA Guideline 1033 on the Provision of AtoN for different classes of vessels, including high speed craft

[17] IALA Guideline 1041 on Sector Lights

[18] IALA Guideline 1051 on the Provision of AtoN in Built-up Areas

[19] IALA Recommendation E-112 for Leading Lights

[20] IALA Recommendation O-138 on the Use of GIS and Simulation by AtoN Authorities

[21] IALA Recommendation O-139 on Marking of Manmade Structures

[22] IALA Recommendation O-117 on The Marking of Offshore Wind Farms

[23] Group Flashing Light Viewing Trial. Pärtel Keskküla. IALA ENG4 input paper ENG4-9.13